

DEVELOPMENT OF CONDITIONAL AND EQUIVALENCE RELATIONS WITHOUT DIFFERENTIAL CONSEQUENCES

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Two experiments were conducted to establish conditional stimulus relations without differential consequences and to test for the emergence of other relations. In Experiment 1, 3 adults responded to match-to-sample displays in which sample-comparison pairs were constant while the second comparison presented with each pair changed periodically across trials. No differential consequences followed any comparison selections. All subjects learned conditional relations between constant samples and comparisons, but results of tests for transitivity in those relations were equivocal. In Experiment 2, 4 children were given unreinforced training and testing similar to that provided to the adults in Experiment 1, with procedural refinements. One child learned conditional relations and demonstrated emergent relations that confirmed the development of two four-member equivalence classes. Another child learned the conditional relations but did not demonstrate any emergent relations reliably. A 3rd child, after reinforced training on two conditional relations, learned four new conditional relations without differential consequences and demonstrated symmetry but not equivalence in the trained relations. The 4th child did not learn the conditional relations. These findings emphasize the importance of careful construction of tests for stimulus equivalence and suggest a need for critical analyses of the apparent emergence of untrained stimulus relations on unreinforced tests that has been observed in several stimulus equivalence studies.

Key words: match to sample, conditional discrimination, stimulus relations, stimulus equivalence, reinforcement, touchscreen response, adults, children

Sidman's stimulus equivalence paradigm (Sidman et al., 1982; Sidman & Tailby, 1982) has provided useful methods for analyzing and teaching complex behavior; it has also stimulated considerable theoretical debate (e.g., Hayes, 1989; McIntire, Cleary, & Thompson, 1989; K. Saunders, 1989; Vaughan, 1989). Many experiments based on this paradigm have shown that humans who learn conditional relations among nonidentical stimuli often demonstrate new conditional relations without instructions or reinforcement. If these emergent performances are consistent with

three relational properties borrowed from mathematics, the relation among the stimuli is equivalence. The property of reflexivity is inferred when each stimulus is shown to be related conditionally to itself without explicit training. When a subject learns a conditional relation between Stimulus A and Stimulus B (e.g., through reinforcement for selecting comparison Stimulus B if and only if Stimulus A is the sample on match-to-sample trials), he or she might also respond to A as a comparison given B as the sample on unreinforced tests. If the subject does so, the property of symmetry is documented. To test for the third property, transitivity, two trained conditional relations are necessary. After learning to select Comparison B when A is the sample and to select another comparison, C, when B is the sample, the learner might then show on unreinforced tests that Sample A and Comparison C are also related conditionally. When all three properties are shown, the stimuli are said to be members of an equivalence class.

To date, most inferences about stimulus equivalence have been drawn from experiments that used standard match-to-sample procedures, including explicit differential con-

This research fulfilled a requirement for the first author's Masters degree in Behavior Analysis and Therapy from Southern Illinois University at Carbondale. It was supported in part by NICHD Grants 5-P30HD02528 and 1-PO1HD18955 to the Bureau of Child Research, University of Kansas. The computer software was developed by Judith Wachter and Richard Saunders. We are grateful to Bill Dube and Murray Sidman for their perceptive comments on a draft of this article. A summary of the research was presented at the 1989 meeting of the Association for Behavior Analysis, Milwaukee. Correspondence and reprint requests should be addressed to Gina Green, Behavior Analysis Department, E. K. Shriver Center for Mental Retardation, Inc., 200 Trapelo Road, Waltham, Massachusetts 02254.

sequences. Responses consistent with sample-comparison relations designated by the experimenter were reinforced by contingent presentation of tokens, chimes, points, or some other consequences, while other responses were not reinforced (e.g., Devany, Hayes, & Nelson, 1986; Dube, McIlvane, Mackay, & Stoddard, 1987; R. Saunders, Wachter, & Spradlin, 1988; Sidman, 1971; Sidman, Kirk, & Willson-Morris, 1985). Then tests, also conducted typically in match-to-sample contexts, evaluated the three relational properties required to justify a conclusion that the stimuli were related by equivalence. Many subjects demonstrated untrained conditional relations the first time they were tested, but several different investigators reported the same rather puzzling observation: For some subjects, performances improved simply with retesting, so that the emergent relations appeared to develop during unreinforced tests (e.g., Devany et al., 1986; Lazar, Davis-Lang, & Sanchez, 1984; Lazar & Kotlarchyk, 1986; R. Saunders, Wachter, & Spradlin, 1988; Sidman et al., 1985; Sidman, Willson-Morris, & Kirk, 1986; Sigurdardottir, Green, & Saunders, 1990; Spradlin, Cotter, & Baxley, 1973). Such observations raised questions about the role of testing in the emergence of equivalence, and exactly when equivalence relations develop (cf. Devany et al., 1986; Lazar et al., 1984; Sidman, in press; Sidman et al., 1986; Sigurdardottir et al., 1990).

Recently, R. Saunders, Saunders, Kirby, and Spradlin (1988) reported that mentally retarded subjects responded conditionally on novel match-to-sample tasks without differential consequences after they had learned other conditional relations with differential consequences. In two experiments, subjects given sample stimuli from two established equivalence classes consistently selected particular comparison stimuli from two other classes on unreinforced trials. Further, the classes linked by the subject-selected unreinforced conditional selections merged, so that new equivalence relations developed from the unreinforced relations. In a third experiment, 2 subjects from the second experiment were presented with novel stimuli in a two-choice match-to-sample arrangement. Each novel sample controlled the selection of a particular novel comparison after just a few trials of this type, even though there were no programmed reinforcement contingencies in effect. That is, new conditional relations were learned with-

out differential consequences. Tests then revealed that equivalence classes emerged from those conditional relations.

The conditional relations in the study by R. Saunders, Saunders, Kirby, and Spradlin (1988) were subject selected and thus not predictable. The subjects also had explicit recent histories of conditional discrimination training in the experimental setting. Some authors, however, have suggested that subjects with a general, nonexperimental history of discriminative responding and behaving consistently might also respond consistently when only one source of stimulus control is constant across unreinforced trials (e.g., Devany et al., 1986; Sidman, in press). If so, it should be possible to arrange experimental tasks to produce predictable conditional relations entirely without differential consequences. Such a demonstration would imply that some reported cases of delayed emergence of equivalence relations might instead be cases in which subjects learned new relations during testing because the test trials established a constant source of stimulus control that was independent of relations trained previously and independent of stimulus equivalence.

To test these possibilities, we designed two experiments to address the following questions: (a) Would subjects who did not have explicit histories of reinforced conditional discrimination training in the experimental setting learn conditional relations without differential consequences? (b) Could we arrange unreinforced conditional discrimination trials to produce predictable, experimenter-designated conditional relations? (c) If the answer to the first two questions was "yes," would other, untrained relations emerge from the unreinforced conditional relations?

In Experiment 1, 3 laboratory-naive adults learned conditional relations without differential consequences. They responded to a series of match-to-sample trials on which pairs of stimuli always appeared together as samples and "correct" comparisons while the "incorrect" comparisons appearing with them changed periodically. Experiment 2 replicated the first with 4 children, with procedural refinements based on the results of Experiment 1.

GENERAL METHOD

This section describes procedures that were common to both experiments. Variations in

procedures and specific conditions are described in the presentation of each experiment.

Apparatus

An Apple IIe® microcomputer system with a standard Apple® monochrome monitor, Personal Touch® touch-sensitive screen, printer, and specially designed match-to-sample software controlled all experimental sessions (stimulus presentation, timing, data recording and analysis). Operation of the apparatus is described below under General Procedures.

Subjects, Setting, and Sessions

All subjects were recruited by personal contact. Prior to the first session and periodically throughout their participation, subjects were instructed not to discuss the research with anyone.

Sessions were conducted in a sound-attenuating room (2.7 m by 3.3 m) that contained the apparatus, two chairs, two tables, and a videocamera for monitoring sessions from an adjacent room. The subject was seated at the table facing the computer monitor. Sessions were 1 to 2 hr long and were conducted 5 days per week. The 3 adult subjects all completed their participation in Experiment 1 within 2 weeks. The 4 children in Experiment 2 participated for 3 to 5 weeks each.

Stimuli

Abstract figures drawn by the computer's high-resolution graphics served as stimuli. Each figure measured approximately 3.3 cm by 2.7 cm when it appeared on the computer screen. For convenience in this presentation, each stimulus is labeled with a letter and a number (e.g., A1, B1, B2, C2), the numbers identifying stimuli that were members of the same experimenter-defined class. Conditional relations are designated by the alphanumeric codes for the sample and correct comparison. For example, A1B1 denotes a conditional relation in which A1 is the sample and B1 is the correct comparison.

General Procedures

Two choice simultaneous match-to-sample procedures were used in all conditions. Sessions consisted of several sets of 16 trials each. The number of sets completed per session varied unsystematically across subjects. The positions of the comparison stimuli and the sequence of trials within each set were quasi-

random, with the restriction that no sample appeared on more than three consecutive trials. No consequences except an intertrial interval followed any responses in this study. Generally, criterion was met when the subject's responses were consistent with the experimenter-designated conditional relations on at least 30 of 32 consecutive trials (15 of 16 trials on two consecutive sets). If criterion was not met on a set that was designed to teach conditional relations (described below), the set was repeated a maximum of 40 times. Each set designed to test potential emergent relations was administered at least twice. If criterion was not met within six test sets, trained relations were reviewed and tests were readministered.

To start the first session, the experimenter prepared the computer and remained in the room, standing a few feet behind the subject. On the first trial, when the sample appeared in the center of the screen the subject was instructed to "touch." A response to the sample was followed by onset of two comparison stimuli, one on each side of the sample, such that the distance from the center of the sample to the center of either comparison was about 7.2 cm. The sample remained on the screen. The subject was instructed to "touch again." Additional responses to the sample had no effect. When the subject touched a comparison stimulus, the screen became blank for 2 s, and then another trial was presented. If the subject did not touch one of the comparison stimuli, he or she was instructed to "touch again" until he or she touched one of the comparison stimuli. The experimenter then left the room, and no other instructions were provided. Due to software limitations, the experimenter had to reenter the room after every set of 16 trials to start the next set but did not interact further with the subject.

EXPERIMENT 1

The first experiment considered whether adults without laboratory conditional discrimination experience would learn predictable conditional relations without differential consequences. This possibility was suggested when the first author observed a subject in another experiment completing unreinforced match-to-sample tests for emergent relations following reinforced conditional discrimination training. In those test sets, pairs of stimuli (e.g., B1 and

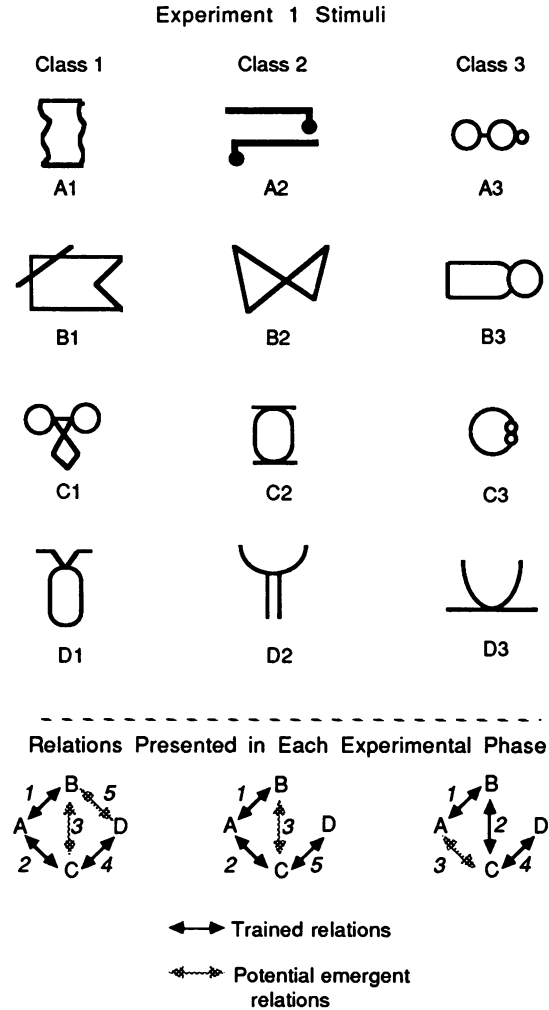


Fig. 1. Representation of stimuli and conditional relations in Experiment 1. Diagrams in the lower portion of the figure summarize the trained and emergent conditional relations for the class of stimuli in the corresponding column. Arrows in these diagrams point from sample to comparison stimuli, and the numbers indicate the experimental phases in which relations were trained or tested.

C1) always appeared together as sample and comparison while the other comparison appearing with them changed occasionally within a set. We speculated that, with repeated exposures to such trials, a naive subject might discriminate that the two unchanging stimuli were related conditionally, even when no differential consequences followed any trials. For this experiment, we simply selected some of the test sets used in the prior experiment and presented them to our naive subjects entirely

without programmed differential consequences. There was no particular rationale relevant to this experiment for the incorrect comparisons used in any phase; they had been selected by another experimenter to make up some of the test sets for a different experiment.

Twelve stimuli, in three experimenter-defined classes of four stimuli each, were used. They are shown in Figure 1. We selected sets of trials that could establish certain conditional relations and permit testing of emergent relations in each of the three classes, but the relations differed somewhat from class to class (as shown in the lower portion of Figure 1). The conditional relations presented in each phase of the experiment are represented in Figure 2 and are described below with the results of each phase.

PROCEDURES AND RESULTS

Subjects

Three adult subjects volunteered for the first experiment. Subject LM, a male, age 25, was a Master's degree student in communicative disorders. Subject KF was LM's wife, age 23, who was a secretary with a 2-year degree in interior design. Subject LM completed the entire experiment before Subject KF started. Subject TM, a 25-year-old male, was an undergraduate geology student. His participation did not overlap with that of either of the other subjects. All subjects were instructed not to discuss the experiment with anyone during their participation.

Phase 1: AB and BA, Classes 1, 2, and 3

Three pairs of stimuli were arranged in six trial types (Figure 2). Each combination of a sample and two comparison stimuli constituted a trial type, and each trial type appeared two or three times in one 16-trial set. When one stimulus in each pair was a sample (e.g., A1), the other member of the pair was designated the S+ (e.g., B1), and another stimulus (e.g., B2) was the S-. On trial types in which the sample and comparison functions for a pair of stimuli were reversed (e.g., when B1 was the sample and A1 was the S+), the S- was different (e.g., B3). Thus, trial types displaying inverse sample-comparison relations (e.g., A1B1 and B1A1) were presented in the same set of trials, and there was one S- per sample-S+ combination. We labeled this procedure

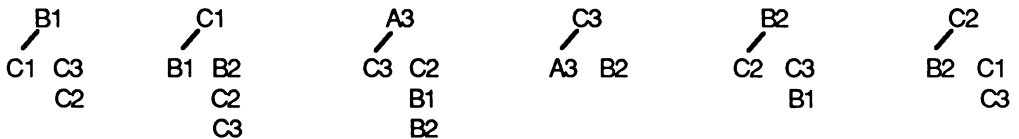
Phase 1: AB,BA - Classes 1, 2 & 3 (inverse/single S-)



Phase 2: AC, CA - Classes 1 & 2; BC, CB - Class 3 (inverse/multiple S-)



Phase 3: BC, CB - Classes 1 & 2; AC, CA - Class 3 (inverse/multiple S-)



Phase 4: CD, DC - Classes 1 & 3 (inverse/multiple S-)



Phase 5: BD, DB - Class 1; CD, DC- Class 2 (inverse/single S-)



Fig. 2. Trial types for each phase of Experiment 1. Each letter-number code represents a stimulus shown in Figure 1. A diagonal line connects the sample and S+ in each predicted conditional relation. Each stimulus that is not connected to a sample served as S- with the sample-S+ pair.

the *inverse/single S-* procedure. The 16-trial set was simply repeated until the subject responded to the S+ on at least 15 trials in each of two consecutive sets.

Results of this phase are shown in Table 1. Subjects LM and KF demonstrated the predicted AB and BA conditional relations consistently after 12 and 15 exposures to this set, respectively. Subject TM required only three exposures.

Phase 2: AC and CA in Classes 1 and 2, BC and CB in Class 3

Phase 2 presented one AC and one CA relation in Classes 1 and 2 and one BC and one

CB relation in Class 3. Inverse sample-S+ relations were presented in the same 16-trial set, but in this phase there were one, two, or three possible incorrect comparisons for each sample-S+ pair (see Figure 2). This is referred to as the *inverse/multiple S-* procedure. Results are shown in Table 1. Acquisition of these conditional relations proceeded much more quickly than Phase 1 acquisition for Subjects LM and KF. This may have been attributable to Phase 1 experience or to the fact that the S- presented with each sample-S+ pair changed more often than in the previous phase, enabling subjects to discriminate more quickly which stimuli did not change.

Phase 3: BC and CB in Classes 1 and 2, AC and CA in Class 3

If the previously established AB/BA and AC/CA relations in Classes 1 and 2 were transitive, the BC and CB relations within those classes should emerge. If the AB/BA and BC/CB relations in Class 3 were transitive, the AC and CA relations in that class should also emerge. In Phase 3, these six potentially emergent relations were presented two or three times each in one 16-trial set (see Figure 2). The inverse/multiple S- procedure remained in effect, however, so there were at least two possible bases for these relations: transitivity in the conditional relations established previously or discrimination of unchanging sample-S+ pairs over trials.

Results are summarized in Table 1. Performances by all 3 subjects met criterion (responses on at least 30 of 32 trials consistent with predicted relations) in the minimum number of sets. It could not be determined, however, whether transitivity in the previously established relations or unchanging stimulus pairs controlled subjects' responses on these trials. Subjects LM and KF had also demonstrated criterion performance in the minimum number of sets in Phase 2, when six new conditional relations were presented that could not have emerged via transitivity.

Phase 4: CD and DC, Classes 1 and 3

This phase presented two new relations each from Classes 1 and 3 (see Figure 2). Each relation appeared four times within the 16-trial set. The inverse/multiple S- procedure was in effect. Results are presented in Table 1. All subjects demonstrated all four relations quickly.

Phase 5: BD and DB in Class 1, CD and DC in Class 2

After the B1C1, C1B1, C1D1, and D1C1 relations were established in Phases 3 and 4, the B1D1 and D1B1 relations were possible via transitivity. (The B3D3 and D3B3 relations were also possible if relations established in preceding phases were transitive, but these were not tested due to experimenter oversight.) Trials that presented B1D1 and D1B1 were mixed with trials presenting novel relations C2D2 and D2C2, as shown in Figure 2. The inverse/single S- procedure used in Phase 1 was in effect here. Results are shown in Table

1. Subject LM failed to demonstrate the C2D2 and D2C2 relations the first time each was presented, but otherwise all responses by all subjects were consistent with all relations.

DISCUSSION

In this experiment, 3 adults learned conditional relations without differential trial-by-trial consequences. Two variations of changing S- procedures were used to establish the conditional relations: the inverse/single S- procedure, in which the incorrect comparison changed only when the inverse of a particular sample-S+ relation appeared; and the inverse/multiple S- procedure, in which the incorrect comparison with each sample-S+ pair changed almost every time the pair appeared within a set of trials. After some experience with such trials, subjects responded as if the members of the unchanging stimulus pairs were the same, and were different than the S-. Both procedures proved to be effective for establishing reliable conditional responding without differential consequences.

This experiment provided no unequivocal evidence for the property of transitivity in conditional relations established without differential consequences. Phase 3 presented trials on which either transitivity in established relations or unchanging sample-comparison pairs could have controlled responding, so no strong conclusions about emergent relations were supported. In Phase 5, the subjects responded almost as consistently on trials that presented novel relations as they did on trials that tested for transitivity in relations established previously. A likely source of stimulus control in Phase 5 trials was the S-. Every stimulus that served as an S- in this phase had been related consistently with another sample in preceding phases (e.g., D3 participated in a conditional relation with C3 in Phase 4), and those samples were not present on Phase 5 trials (see Figure 2). Subjects may have responded away from the S- on each trial on this basis, rather than demonstrating an emergent relation between the sample and the other available comparison (i.e., exclusion; McIlvane & Stoddard, 1981, 1985). In the next experiment we sought to assess more conclusively whether untrained conditional relations would emerge from conditional relations established by the changing S- procedures.

Table 1

Number of 16-trial sets to criterion performance of conditional relations, Experiment 1.

Phase	Relations	Subjects		
		LM	KF	TM
1	AB, BA—Classes 1, 2, and 3	12	15	3
2	AC, CA—Classes 1 and 2; BC, CB—Class 3	2	2	3
3	BC, CB—Classes 1 and 2; AC, CA—Class 3 (transitivity test)	2	2	2
4	CD, DC—Classes 1 and 3	4	2	4
5	BD, DB—Class 1 (transitivity test); CD, DC—Class 2	3	2	2

EXPERIMENT 2

The rapid development of unreinforced conditional responding by the adults in Experiment 1 may have been the result of long preexperimental histories of reinforcement for conditional responding. The second experiment attempted to replicate the findings of Experiment 1 with children who had less extensive general histories.

METHOD

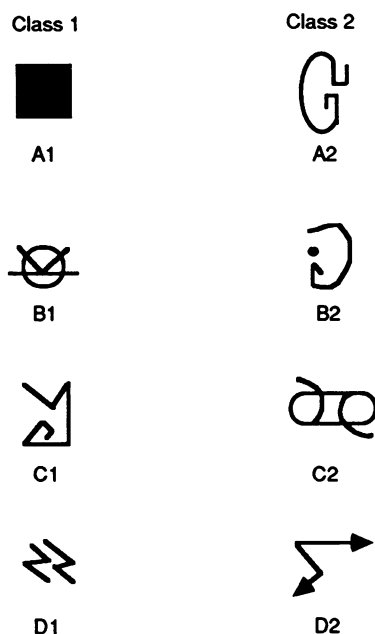
Subjects

Four children volunteered for this experiment. All attended regular elementary or middle school classes, and none of them (or their parents) reported that they had ever participated in laboratory learning research. Subjects were FO, female, age 12; OM, male, age 11; CF, male, age 12; and MT, male, age 9. Subject MT did not complete the first two phases successfully and terminated participation at that point; none of his data are presented.

Apparatus, Setting, and Stimuli

The apparatus and setting were the same as for Experiment 1. Stimuli in two experimenter-defined classes of four stimuli each were used in this experiment. They are represented in Figure 3. The conditional relations trained and tested in both classes are illustrated in the lower portion of Figure 3.

Experiment 2 Stimuli



Relations Presented in Each Experimental Phase
Classes 1 and 2

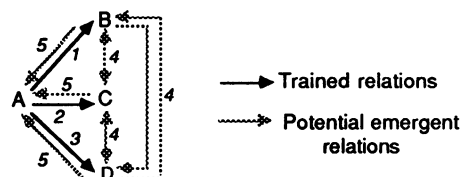
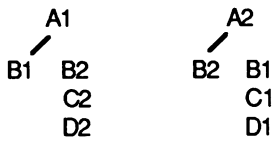


Fig. 3. Representation of stimuli and conditional relations in Experiment 2. The diagram in the lower portion of the figure summarizes the trained and emergent relations for both classes of stimuli. Arrows in this diagram point from sample to comparison stimuli, and the numbers indicate the experimental phases in which relations were trained or tested.

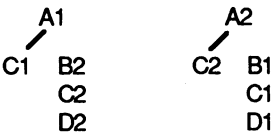
PROCEDURES AND RESULTS

The procedures were modified, based on the results of the first experiment, as follows: In training phases (1–3), the A stimuli were used only as samples, no inverse trial types were presented in the same set, and the S– varied each time a trial type appeared (termed the *no inverse/multiple S–* procedure). For example, in Phase 1 when A1 was the sample, B1 was always available as a comparison, B1 never appeared as a sample within the same set, and the other comparison varied among B2, C2,

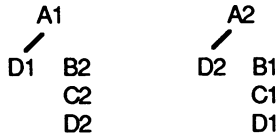
Phase 1: AB (no inverse/multiple S-)



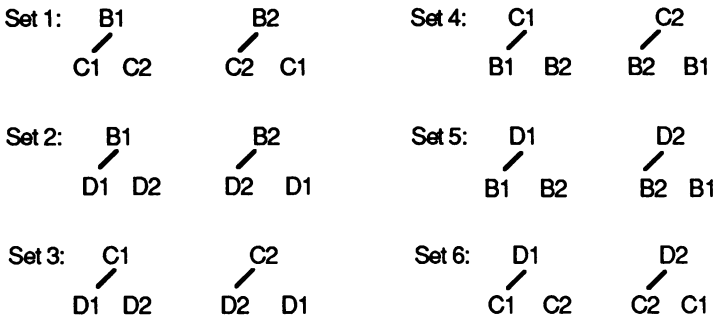
Phase 2: AC (no inverse/multiple S-)



Phase 3: AD (no inverse/multiple S-)



Phase 4: Equivalence Test (no inverse/single S-)



Phase 5: Symmetry Test (no inverse/single S-)

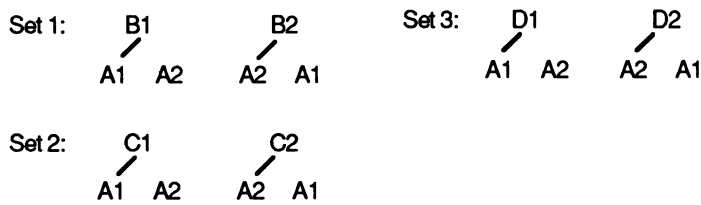


Fig. 4. Trial types for each phase of Experiment 2. Each letter-number code represents a stimulus shown in Figure 3. A diagonal line connects the sample and S+ in each predicted conditional relation. Each stimulus that is not connected to a sample served as S- with the sample-S+ pair.

and D2 across trials. These changes made it possible to assess whether the changing S—alone, without concurrent presentation of inverse relations, was sufficient to establish conditional relations. They also allowed us to test for symmetry directly, which was not possible in Experiment 1 because all relations were established bidirectionally (e.g., both AB and BA were trained in Experiment 1). Two equivalence classes were possible. Each experimental phase is represented in Figure 4 and is described below. No differential consequences followed any comparison selections, with one exception described below. After they completed the experiment, the children were asked questions about how they responded during the experiment.

Phase 1: AB

Three different sets of 16 trials each were designed to establish the A1B1 and A2B2 conditional relations. Within sets, the prospective A1B1 and A2B2 relations appeared eight times each, and the S— appearing with each AB pair varied among those shown in Figure 4 for this phase. Over the three sets cumulatively, each S— appeared an equal number of times. The three AB sets were presented consecutively until the subject demonstrated the predicted relations on at least 15 of 16 trials for two consecutive sets.

Results are shown in Table 2. Two subjects, FO and OM, demonstrated the predicted AB relations in five and 12 sets, respectively. Subject CF did not demonstrate the AB conditional relations after 34 sets, so the procedure was modified as follows: The AB relations were trained directly by presenting a computer-generated jingle following correct comparison selections and a buzzer following incorrect selections. To start this training, the subject was told that when he heard a jingle it meant that he had chosen the correct figure, and the buzzer meant that he had chosen the incorrect figure. No other instructions were provided. Criterion performance was demonstrated after seven reinforced sets (for a total of 41 AB sets).

Phase 2: AC

Phase 2 was conducted like Phase 1, except that no subjects experienced any programmed consequences in this phase. Three sets were presented to train the AC relations. Trial con-

Table 2

Number of 16-trial sets to criterion performance of conditional relations in Phases 1–3, Experiment 2.

Phase	Relations	Number of sets for indicated subject		
		FO (age 12)	OM (age 11)	CF (age 12)
1	AB	5	12	41
2	AC	3	5	3
3	AD	2	2	2

figurations are shown in Figure 4. Results are summarized in Table 2. All 3 subjects reached criterion on the predicted AC relations relatively quickly.

Phase 3: AD

The AD relations were presented in the same fashion as the AB and AC relations (refer to Figure 4). Results are shown in Table 2. All 3 subjects demonstrated criterion performance on the predicted AD relations within two sets.

Phase 4: Equivalence Test

Next, the children completed tests for equivalence. These tests used the no inverse/single S— procedure to minimize opportunities for subjects to learn the tested relations during repeated exposure to unchanging sample–correct comparison pairs with changing incorrect comparisons. Two relations were tested eight times in each set, and each set was presented at least twice (see Figure 4 for trial types). The test sets were administered in the order shown in Figure 4, but if a subject had below-criterion scores on two different test sets, he or she was given a review of the AB, AC, and AD relations (without reinforcement) before testing resumed.

Results of Phase 4 tests for Subject FO are shown in Table 3. She demonstrated all tested relations immediately and on every test trial. These results suggested that the AB, AC, and AD conditional relations, all established without differential consequences, were also equivalence relations.

Subject OM demonstrated tested relations reliably on the first administration of some of the test sets, but performance on other sets was near chance. After a review of the previously established relations, his performance on all

Table 3

Number of responses on 16-trial tests consistent with equivalence and symmetry, Subjects FO and CF, Experiment 2.

Phase	Relations	FO	CF
4	Equivalence test		
	Set 1: BC	16, 16	Did not meet criterion on any sets
	Set 2: BD	16, 16	
	Set 3: CD	16, 16	
	Set 4: CB	16, 16	
	Set 5: DB	16, 16	
	Set 6: DC	16, 16	
5	Symmetry test		
	Set 1: BA	16, 16	1, 0, (AB), 0, (AB), 16, 15 [(AB, AC, AD), 16]
	Set 2: CA	15, 16	(AC), 16, 15 [(AB, AC, AD), 16]
	Set 3: DA	16, 16	(AD), 16, 16 [(AB, AC, AD), 16]

Note. Letters in parentheses represent conditional relations that were reviewed (without consequences) between symmetry test sets. Brackets indicate procedures conducted once after completion of initial Set 3 symmetry tests.

test sets was near chance. This subject elected to leave the experiment at this point, and his data are not shown.

Subject CF's tests failed to produce consistent evidence for equivalence, despite two reviews of the relations established in preceding phases and two retests. The absence of equivalence suggested that the established relations might not be symmetrical, so this subject proceeded to Phase 5 symmetry tests. Even after symmetry was established (described below) and the trained relations were reviewed again, CF's performances were inconsistent from one equivalence test to another. His equivalence test data are not shown.

Phase 5: Symmetry Test (BA, CA, and DA)

Tests for symmetry used the no inverse/single S- procedure. There were three sets of 16 trials; each set tested two relations, and each was presented twice initially (see Figure 4 for trial types). Results are shown in Table 3. Subject FO demonstrated symmetry in all the trained relations immediately and reliably. Subject CF's performances on the first two sets of tests for BA relations were at or near zero. One unreinforced review of the AB relations failed to effect a change in BA performance, but after a second review of the AB relations, symmetry was demonstrated. Then a review of the AC relations was followed by positive CA tests, and a review of AD was followed by positive DA tests. Finally, all AB, AC, and AD relations were reviewed and one repetition of each Phase 5 test set confirmed symmetry in all trained relations. Scores on all reviews met criterion.

Debriefing

When their participation ended, each subject was asked about the tasks they had just completed. General questions included "What did you do?" "Did you learn anything?" "Did the same shapes appear or were they always different?" "Were any shapes related?" The subject's verbal responses to these questions were recorded in writing by the experimenter.

During debriefing Subject FO stated that she knew that some shapes kept reappearing together. When asked why she responded as she did when the figures did not change from trial to trial (equivalence and symmetry tests, Phases 4 and 5), she said "I just picked the one I thought was right." Subjects OM and MT stated that they thought the shapes were always changing and they could not figure out what to do. When OM was asked why he was matching some shapes at one time and then stopped doing so, he said he did not know he had done that, and then said that he got bored doing the same thing over and over. Subject CF said it took him a while but that he finally understood that some shapes kept appearing together, and they were the ones he matched. He also said, "I couldn't figure out some of them because the shapes were always the same and none of them changed" (the tests for equivalence and symmetry).

DISCUSSION

In this experiment, 1 child (FO, a 12-year-old female) performed much like the adult subjects in Experiment 1. She learned conditional relations without differential consequences

with a changing S- procedure; further, she demonstrated the development of two equivalence classes. An 11-year-old boy (OM) learned the unreinforced conditional relations but gave no evidence that stimulus equivalence emerged. Two boys, ages 9 (MT) and 12 (CF), did not demonstrate reliable conditional responding under the same conditions. The reason for this is not clear. Subject CF received reinforced training on two conditional relations, and then learned four others with the changing S- procedure but no consequences. An interesting outcome of the debriefing was that 2 of the 3 subjects who learned the conditional relations (FO and CF) described the procedures quite accurately. The subject who did not learn any conditional relations (MT) stated that he "did not know what was happening." Subject FO, who performed perfectly on virtually all tests for emergent relations, did not verbalize any rules or descriptions of stimulus relations when asked after the fact to explain her responses on those tests.

GENERAL DISCUSSION

Experiment 1 showed that predictable conditional relations could be taught without differential consequences to adult subjects who had no laboratory conditional discrimination training histories. Tests for potential emergent relations were rendered inconclusive because the test trial arrangements made it possible for subjects to learn the tested relations just as they had learned other relations (i.e., by discriminating constant sample-S+ pairs from changing incorrect comparisons). In Experiment 2 we used a changing S- procedure to teach conditional relations to 4 children. This procedure was sufficient to establish six conditional relations with 2 children (FO and OM). A 3rd child (CF) learned four relations (AC and AD) under the changing S- condition without differential consequences only after reinforced training on two relations (AB). The 4th child failed to demonstrate any conditional relations reliably under the changing S- condition, even after extensive exposure to the procedures, but did not have any reinforced training (like CF). Experiment 2 was designed to provide more conclusive evidence than Experiment 1 that untrained relations emerged from training with the changing S- procedure by ensuring that none of the tests for equivalence and symmetry presented more than one

S- with the same sample-S+ pair. Subject FO demonstrated the emergence of 18 untrained conditional relations to document the development of two four-member equivalence classes entirely without programmed differential consequences. Subject OM did not demonstrate any emergent relations reliably. Subject CF failed to demonstrate equivalence, but symmetry in the trained relations emerged after reviews.

These findings make it clear that tests for emergent stimulus relations must be constructed very carefully if they are to support valid inferences about untrained controlling relations. If test trials are arranged in certain ways, subjects may learn new relations simply because pairs of stimuli make up constant portions of otherwise changing stimulus arrays. It appears that presenting a different S- on each test trial with a particular sample-S+ pair, as suggested by Fields, Verhave, and Fath (1984), is very likely to establish an alternative source of stimulus control that can compete successfully with stimulus equivalence, even when tests are run in extinction. Such artifacts can produce test performances that might be taken as evidence that stimulus equivalence has emerged from trained conditional relations, when in fact the outcome is independent of that training.

Several investigators who reported apparent acquisition of untrained relations during testing evaluated some inverse relations in the same testing sets or sessions (e.g., Devany et al., 1986; Lazar et al., 1984; Lazar & Kotlarchyk, 1986; R. Saunders, Wachter, & Spradlin, 1988; Sigurdardottir et al., 1990; Stromer & Osborne, 1982). Across trials that presented the same pair of stimuli (e.g., B1 and C1) in inverse sample-comparison arrangements, the S- necessarily varied; for example, when B1 was the sample C1 and C2 were comparisons, and when C1 was the sample B1 and B2 were comparisons. But in most cases test trials were balanced within sets so that *all* sample-comparison pairs, not just the predicted ones, were equally probable. In the same example test set, when C2 was the sample the comparisons were B1 and B2. Thus B1 and C2 also appeared together consistently as sample and comparison while the other comparison presented with them changed across trials (e.g., R. Saunders, Wachter, & Spradlin, 1988; Sigurdardottir et al., 1990). There seems to be no reason (aside from the development of stimulus equivalence)

for one consistent sample-comparison relation rather than the other to gain control as tests like these are repeated, but that may depend critically on prior training, physical features of the stimuli, and the first few trial arrangements the subject sees on a test (cf. Sidman, in press). Results of experiments in which inverse relations within prospective equivalence classes (e.g., B1C1 and C1B1) are tested in the same test sets or sessions and test trials are not balanced in this fashion should be interpreted cautiously.

Other investigators who reported delayed emergence of untrained relations during testing did not include inverse trial types in the same test set or session, and always presented the same S- with a given sample-S+ pair (e.g., Sidman et al., 1985, 1986; Spradlin et al., 1973). We called this the no inverse/single S- procedure and used it in our tests for emergent relations in Experiment 2. This seems to be a conservative algorithm to use for constructing test trials, but it may not preclude the development of control by consistent sample-S+ pairs across different test sets or sessions (e.g., BC relations in one set, CB relations in another) if trial configurations are not balanced across test sets so that all sample-comparison relations are equally probable, as discussed above.

One plausible explanation for delayed emergence of equivalence is that several sources of stimulus control are present when testing begins, but stimulus equivalence is the only option that is available consistently over all the test trials (Devany et al., 1986; Sidman, in press). Our results confirm that humans can discriminate consistent from inconsistent sources of stimulus control with repeated exposures to unreinforced match-to-sample trials. The results also suggest that testing can function to teach entirely new stimulus relations, which raises this question: Do all cases of apparent delayed development of equivalence actually document the emergence of equivalence in trained conditional relations, or do some of them show merely that humans can learn conditional relations without reinforcement given sufficient exposure to the right stimulus arrangements?

Our experiments used two-choice match-to-sample tasks on which there was only one correct response per trial. On such trials, any of several sources of stimulus control might de-

termine comparison selection. For example, the subject may respond away from a comparison stimulus because it is related conditionally to another stimulus that is not present. Alternatively, the subject may learn that selection of a comparison in the presence of a particular sample is never reinforced and thus respond away from that comparison on subsequent trials. If either type of stimulus control is a possibility on a test trial, emergent stimulus equivalence is confounded with the other source of control. Providing more than two comparisons per trial reduces the likelihood of confounding by some kinds of unwanted stimulus control (Sidman, 1987). On tests that use changing S- procedures, however, the presence of more than one changing S- across trials may enhance the discriminability of consistent sample-S+ relations and establish competing control even more quickly than two-choice procedures do.

REFERENCES

- Devany, J. M., Hayes, S. C., & Nelson, R. O. (1986). Equivalence class formation in language-able and language-disabled children. *Journal of the Experimental Analysis of Behavior*, **46**, 243-257.
- Dube, W. V., McIlvane, W. J., Mackay, H. A., & Stoddard, L. T. (1987). Stimulus class membership established via stimulus-reinforcer relations. *Journal of the Experimental Analysis of Behavior*, **47**, 159-175.
- Fields, L., Verhave, T., & Fath, S. (1984). Stimulus equivalence and transitive associations: A methodological analysis. *Journal of the Experimental Analysis of Behavior*, **42**, 143-157.
- Hayes, S. C. (1989). Nonhumans have not yet shown stimulus equivalence. *Journal of the Experimental Analysis of Behavior*, **51**, 385-392.
- Lazar, R. M., Davis-Lang, D., & Sanchez, L. (1984). The formation of visual stimulus equivalences in children. *Journal of the Experimental Analysis of Behavior*, **41**, 251-266.
- Lazar, R. M., & Kotlarchyk, B. J. (1986). Second-order control of sequence-class equivalences in children. *Behavioural Processes*, **13**, 205-215.
- McIlvane, W. J., & Stoddard, L. T. (1981). Acquisition of matching-to-sample performances in severe retardation: Learning by exclusion. *Journal of Mental Deficiency Research*, **25**, 33-48.
- McIlvane, W. J., & Stoddard, L. T. (1985). Complex stimulus relations and exclusion in mental retardation. *Analysis and Intervention in Developmental Disabilities*, **5**, 307-321.
- McIntire, K. D., Cleary, J., & Thompson, T. (1989). Reply to Saunders and to Hayes. *Journal of the Experimental Analysis of Behavior*, **51**, 393-396.
- Saunders, K. J. (1989). Naming in conditional discrimination and stimulus equivalence. *Journal of the Experimental Analysis of Behavior*, **51**, 379-384.
- Saunders, R. R., Saunders, K. J., Kirby, K. C., & Sprad-

- lin, J. E. (1988). The merger and development of equivalence classes by unreinforced conditional selection of comparison stimuli. *Journal of the Experimental Analysis of Behavior*, **50**, 145-162.
- Saunders, R. R., Wachter, J., & Spradlin, J. E. (1988). Establishing auditory stimulus control over an eight-member equivalence class via conditional discrimination procedures. *Journal of the Experimental Analysis of Behavior*, **49**, 95-115.
- Sidman, M. (1971). Reading and auditory-visual equivalences. *Journal of Speech and Reading Research*, **14**, 5-13.
- Sidman, M. (1987). Two choices are not enough. *Behavior Analysis*, **22**, 11-18.
- Sidman, M. (in press). Equivalence relations: Some basic considerations. In L. R. Hayes & S. C. Hayes (Eds.), *Dialogues on verbal behavior: Proceedings of the Third International Institute on Verbal Relations*. Reno, NV: Context Press.
- Sidman, M., Kirk, B., & Willson-Morris, M. (1985). Six-member stimulus classes generated by conditional-discrimination procedures. *Journal of the Experimental Analysis of Behavior*, **43**, 21-42.
- Sidman, M., Rauzin, R., Lazar, R., Cunningham, S., Tailby, W., & Carrigan, P. (1982). A search for symmetry in the conditional discriminations of rhesus monkeys, baboons, and children. *Journal of the Experimental Analysis of Behavior*, **37**, 23-44.
- Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior*, **37**, 5-22.
- Sidman, M., Willson-Morris, M., & Kirk, B. (1986). Matching-to-sample procedures and the development of equivalence relations: The role of naming. *Analysis and Intervention in Developmental Disabilities*, **6**, 1-19.
- Sigurdardottir, Z. G., Green, G., & Saunders, R. R. (1990). Equivalence classes generated by sequence training. *Journal of the Experimental Analysis of Behavior*, **53**, 47-63.
- Spradlin, J. E., Cotter, V. W., & Baxley, N. (1973). Establishing a conditional discrimination without direct training: A study of transfer with retarded adolescents. *American Journal of Mental Deficiency*, **77**, 556-566.
- Stromer, R., & Osborne, J. G. (1982). Control of adolescents' arbitrary matching-to-sample by positive and negative stimulus relations. *Journal of the Experimental Analysis of Behavior*, **37**, 329-348.
- Vaughan, W., Jr. (1989). Reply to Hayes. *Journal of the Experimental Analysis of Behavior*, **51**, 397.

Received December 5, 1989
Final acceptance April 25, 1990